Chapter 5

Water quality standards and regulations for agricultural water reuse in MENA:
From international guidelines to country practices

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Key messages

- This chapter analyzes national water quality standards, regulations and guidelines for irrigation water reuse in the MENA region with a focus on Egypt, Lebanon, Morocco, Jordan and Tunisia and compares them to other countries in the region and different international guidelines such as WHO (1989, 2006a), FAO (1992), UNEP (2005) and EPA (2012).
- The five countries still follow a standardized model targeting the formal waste-water sector where treated effluents are to comply with a fixed and often stringent set of standards to be considered safe for reuse.
- Four MENA countries (Egypt, Jordan, Lebanon and Morocco) adopt the model developed by WHO (1989) and three of them (Morocco being the exception) adapted it by setting more stringent microbial thresholds and a complete restriction on vegetables to be eaten raw.
- The WHO (2006a) multi-barrier approach has been widely promoted in the region but does not reflect in countries' regulations despite the development of project-based guidelines, which remain indicative.
- Countries still favor a top-down approach with complete restrictions on certain crops and irrigation techniques regardless of the context. Enforcement is often ineffective with farmers having poor incentives or support to find alternative practices.
- Several factors hinder the design and implementation of more adaptive approaches such as the lack of institutional leadership, technocratic institutional processes to design standards and reluctance to take decisions perceived as unethical or entailing additional responsibilities.
- On a more positive note, the study identified recent research initiatives and field experiments studying risk management measures to propose guidelines adapted to local conditions. Knowledge-building should be expanded, shared with decision-makers in appropriate institutional settings, given visibility and support to influence regulations and policy practices.
- There is a need for more systemic research on regulations in the region that goes beyond the traditional technocratic reflection on standards and borrow from the fields of human geography and political economy to study decision-making processes, institutions and local practices.

5.1. Introduction and objectives

While water reuse offers multiple benefits, it also comes with concerns on its potential impact on health, crops and ecosystems. To manage these hazards, governments typically issue water quality 'standards' usually promulgated through regulations centered around several water quality parameters and thresholds, monitoring protocols and best practices (Box 5.1).

BOX 5.1 Terminology

Standards: A rule, principle or measure typically including qualitative restrictions in terms of numerical limits. Water quality standards for agricultural water reuse include physicochemical, health-based and agronomic parameters. Typically, they are formulated according to different categories of use applications or level of restriction on uses.

Regulations: They are compulsory dispositions, officially promulgated by state legislature and entail legal responsibilities and sanctions. Water quality regulations for agricultural water reuse typically include standards as well as monitoring protocols. They sometimes include enforcement mechanisms and sanctions.

Guidelines: Standards and best practices usually developed by international expert organizations and followed by countries to promulgate their own regulations.

Source: Adapted from Shoushtarian and Negahban-Azar 2020.

Despite the expanding technical knowledge and disseminated policy guidelines in this field, designing and enforcing water reuse regulations is an uphill battle.

Since the 1970s, international regulatory approaches have evolved considerably to find the right trade-offs between safety and enforceability (Dreschel et al. 2010; Shoushtarian and Negahban-Azar 2020). The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) have progressively adapted their guidelines to support low-income countries ensuring safe water reuse without investing in costly treatment technologies (WHO 1989, 2006a; FAO 1992). The most recent WHO guidelines (2006a) shifted the regulatory paradigm from a 'single barrier' approach where hazard reduction is achieved by treatment to a 'multi-barrier' approach where pathogen elimination measures can be distributed along other less technology-intensive steps such as low-cost treatment, on-farm and post-harvest practices. More generally, there is a growing call for designing adaptive and achievable regulations that consider financial, socioeconomic and institutional circumstances (WHO 2006a, b; Dreschel et al. 2010; EPA 2012; EU 2016).

In the MENA region, agricultural water reuse has been expanding since the 1970s driven by different environmental, economic and socio-political circumstances (see Chapter 3). Often abiding by international guidelines, most countries issued national regulations to manage the safety of water reuse. Some countries, such as Egypt and Jordan, have adapted them several times. Yet experts still underline a need for regulatory improvement in MENA, highlighting excessive levels of stringency, lack of adaptiveness to local contexts and discrepancies between countries, which would skew commercial exchange (WHO 2006b; Choukra-Allah 2010; Ait-Mouheb et al. 2020; MEDAWARE 2003). However, the existing literature does not sufficiently document and analyze these problems, at least not in a comprehensive way: what specific regulatory orientations are favored and why? Do countries abide by the recent international guidelines such as the WHO multi-barrier approach and if not, why? To which specific 'contexts' do regulations fail to correspond? How do decision-making processes shape the design of water-reuse regulations in the region and how these can be enhanced? This work contributes to unpacking these questions.

This chapter analyzes national regulations and guidelines for irrigation water reuse in the MENA region with a focus on five countries: Egypt, Lebanon, Morocco, Jordan and Tunisia. It introduces the main regulatory approaches adopted worldwide with a focus on the WHO (1989, 2006) and FAO (1992) guidelines that proved influential in the region. The second part reviews the historical development of countries' regulations within the larger development of water reuse policies. The third part compares the health-based, agronomic and physicochemical standards against different international guidelines and other MENA country regulations, with a particular interest for human-health standards and restrictions imposed on agricultural practices. The fourth part of the chapter questions the adoption (or lack thereof) of the internationally promoted risk management approaches and unpacks some challenges preventing their translation into national policies and practices. The chapter concludes on common trends in designing qualitative regulations for agricultural water reuse in the MENA region and draws recommendations for future policy and research activities.

5.2. Regulating treated water quality: technical standards and management challenges

5.2.1 International reuse guidelines and their evolution: from the 'zero risk' to the 'multi-barrier' approach

Irrigation from sewage water has been practiced by humans since the Bronze Age (3200–1100 BC). This led to the development of water-borne diseases and epidemics such as cholera and typhoid and pushed governments to start deploying efforts to better collect and treat effluents and regulate their use (Shoushtarian and Negahban-Azar 2020; Ait-Mouheb et al. 2020; Abu-Madi 2004).

The US state of California developed the first regulations in 1918, which influenced policy agendas and research programs worldwide. By the 1970s, the interest in regulating water quality had grown globally and produced substantial technical knowledge on the parameters to be monitored in treated effluents to protect human health and agronomic systems.[1] Those can be grouped into 'human health', 'agronomic' and 'physicochemical' parameters (Figure 5.1).

Two main regulatory approaches took shape, particularly diverging on the stringency level of pathogen control and trade-offs to be made between safety on one hand and cost of treatment on the other (UNEP 2005; Drechsel et al. 2010). With the evolution of scientific studies and the application of regulations in different contexts, regulatory approaches increased in

[1] See Shoushtarian and Negahban-Azar (2020) for a synthetic overview of tested parameters and their impacts.

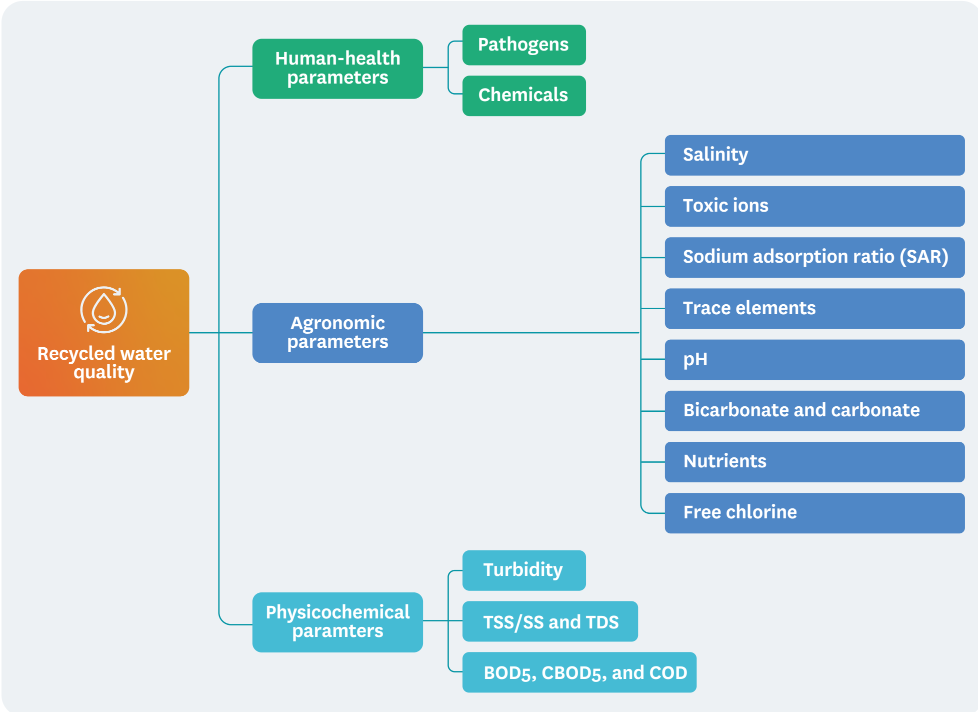

FIGURE 5.1 Main parameters monitored in treated effluents.
SOURCE: Shoushtarian and Negahban-Azar 2020

sophistication with an ambitious aspiration to design, align and monitor further practices to reduce contaminants along the wastewater treatment and reuse chains. The following section presents the main guidelines that have been influential worldwide and more particularly in the MENA region.

The conservative Californian model

The first treated water quality regulations were issued by the US state of California. They instituted a total elimination of pathogens in reclaimed wastewater based on the premise that any pathogenic microorganisms constitute a health hazard. The Californian model promotes a 'zero risk' approach associated with the use of the 'best available technology', (Shoushtarian and Negahban-Azar 2020; Ait-Mouheb et al. 2020). In 1973, the World Health Organization (WHO) proposed similar stringent guidelines for pathogen control in irrigation water (UNEP 2005; Bos et al. 2010; Shoushtarian and Negahban-Azar 2020).[2] However, the standards proved difficult to meet especially in low-income countries due the associated high costs of advanced treatment. This challenge drove the development of epidemiological studies and allowed issuing the less stringent guidelines described below (WHO 1989; Bos et al. 2010). The Californian model continued to be favored in higher income countries although some of them opted for the WHO guidelines (UNEP 2005).[3] The Californian model influenced guidelines developed by the United States Environmental Protection Agency (Shoushtarian and

[2]Threshold of 100 coliforms per 100 mL

[3]Such as France and Italy.

Negahban-Azar 2020; EPA 2012) and is adopted in some high-income MENA countries such as those of the Gulf Cooperation Council (GCC) region (Choukr-Allah 2010; Ait-Mouheb et al. 2020).

The influential WHO (1989) and FAO (1992) guidelines

While treated wastewater volumes remained globally low and unplanned reuse continued to expand in arid and semi-arid countries, the WHO developed a more realistic approach and issued new guidelines in 1989 (Drechsel et al. 2010; Bos et al. 2010). The 1989 WHO guidelines established three different categories of 'use condition' (A, B, C) according to which pathogen thresholds are gradually less restrictive (Table 5.1). Different treatment technologies were recommended for each of these categories which also become gradually less cost demanding. This differentiation between different water uses is intended to allow for more flexibility in the selection of technologies and treatment levels. Guidelines included risk management approaches that would complement available treatment processes or could even be used in the absence of wastewater treatment. Restrictions on certain crops and irrigation techniques (e.g., prohibition of sprinklers) are recommended to reduce pathogen contamination when advanced treatment is not available.

In the same period, FAO (1992) also developed guidelines for water reuse and included the same approach for pathogen control as WHO (1989).[4] FAO added agronomic parameters such as salinity, rate of water infiltration into the soil, specific ion toxicity or some other miscellaneous parameters.[5] The guidelines identified three categories of 'restriction on use' (none, slight to moderate, severe) and for each parameter and level of restriction, recommended

[4]An earlier edition of FAO guidelines for water reuse was issued in 1970 addressing the water-quality challenged of salinity and specific ion toxicity.

[5]Complete guidelines are available at https://www.fao.org/3/t0234e/T0234E01.htm#ch1

TABLE 5.1 WHO guidelines for the safe use of wastewater in agriculture.

Category	Use condition	Exposed group	Intestinal nematodes[b]	Fecal coliforms (geometric mean no. per 100 mL[c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[a]	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8–10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but no less than primary sedimentation

NOTES: [a]In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly; [b]*Ascaris* and *Trichuris* species and hookworms arithmetic mean no. of eggs per liter during the irrigation period; [c]During the irrigation period; [d]A more stringent guideline (< 200 fecal coliforms per 100 mL) is appropriate for public lawns, such as hotel lawns, with which public may come into direct contact. [e] In the case of fruit trees, irrigation should cease two weeks before fruit is picked and no fruit should be picked off the ground. Sprinkler should not be used. *SOURCE*: WHO 1989.

management alternatives to deal with these potential problems (FAO 1992). Both the WHO and FAO pinpoint that guidelines are indicative and need to be adapted to countries' or sites' local conditions. WHO (1989) underlines that the local epidemiological, socio-cultural and environmental factors should be considered and the guidelines modified accordingly (such as microbial thresholds against use conditions) (Table 5.1 above). FAO (1992) points out that water quality classifications are only indicative guidelines, and their application will have to be adjusted to conditions that prevail in the field (climatic conditions, physical and chemical properties of the soil, the salt tolerance of the crop grown and the management practices).

The WHO (1989) and FAO (1992) produced leading guidelines to which countries' regulations have globally referred to including in MENA (UNEP 2005; EPA 2012; Shoushtarian and Negahban-Azar 2020). In 2005, to support Mediterranean countries in establishing suitable standards UNEP, in collaboration with the WHO and researchers from the Mediterranean, proposed *Guidelines for municipal water reuse in the Mediterranean countries,* where a fourth water category has been differentiated with more stringent microbial thresholds (UNEP 2005). This approach has been influential in some countries as seen below.

The WHO (2006) multi-barrier approach

The slow progress in wastewater treatment in developing countries coupled with increasing unsafe reuse practices challenged the application potential of the 1989 WHO guidelines. The WHO (2006a) developed a new regulatory method drawing from the 'Hazard Analysis Critical Control Point' (HACCP) known as the 'multi-barrier approach' (Bos et al. 2010). A major change is the focus on 'health-based targets' to be attainable at the end of the reuse chain instead of prescribing threshold levels that are often unattainable when conventional treatment facilities are lacking or underperforming (Bos et al. 2010; Dreschel et al. 2010). The approach covers both conventional and non-conventional wastewater treatment methods as well as other health-protection measures to meet health targets, be it for the farmer or consumer (Figure 5.2). Non-conventional wastewater treatment methods include the use of low-cost systems such as on-farm ponds, sedimentation traps and biosand-filters while health-protection measures include improved irrigation methods, like drip irrigation, cessation of irrigation before harvesting and produce-washing (WHO 2006; Bos 2010). Health-based targets are measured in DALYs (Disability Adjusted Life Years), which is increasingly becoming an essential unit in comparing disease outcomes from different exposures.[6]

As for earlier guidelines, the WHO (2006a) recommends that countries perform their own studies to set health-based targets and associated pathogen reduction control points based on local conditions. It also offers shortcuts where research capacities are constrained (Bos et al. 2010). Conducting QMRAs (Quantitative Microbial Risk Assessment) is recommended instead of the costly epidemiological studies. Today, although the use of QMRA is growing and allowing for more tailored guidelines, these studies are complicated to perform as they require capable research institutions, strong expertise and data relevant to the specific regions (De Keuckelaere et al. 2015). More generally, the WHO multi-barrier approach is also

[6]See Drechsel et al. 2010 for extensive explanation on this concept and its use in the multi-barrier approach.

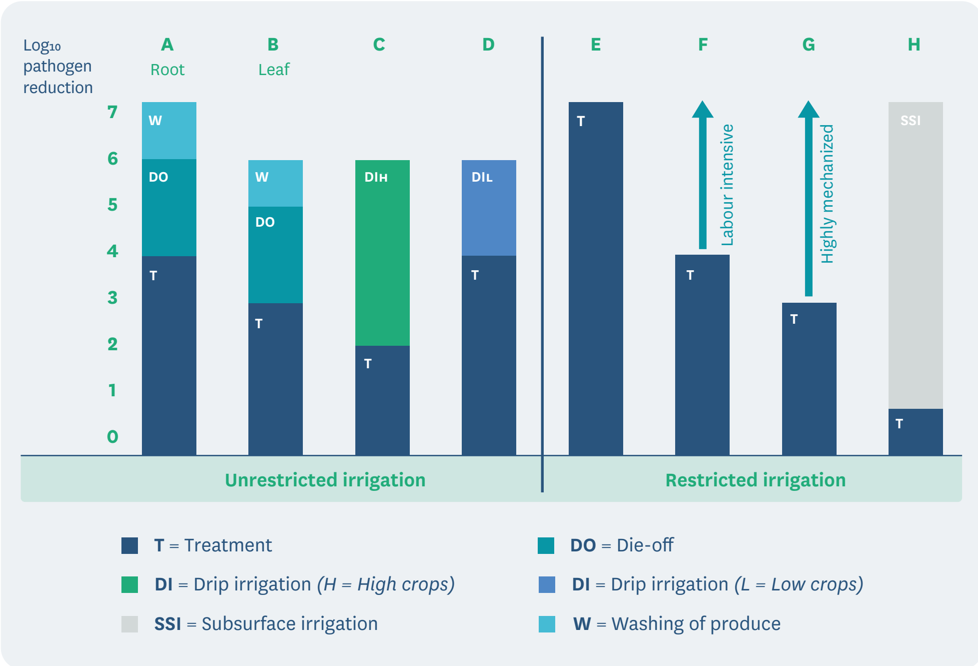

FIGURE 5.2 Examples of options for the reduction of pathogens by different combination of health measures that achieve the health-based targets of ≤ 10-6 DALYs per person per year.
SOURCE: WHO 2006a.

seen as complicated to understand and apply for authorities with weak expertise (Bos et al. 2010). The WHO guidelines (1989) are considered more straightforward, especially for countries that already have comprehensive wastewater collection and treatment in place (Jiménez et al. 2010).

5.2.2. The multi-level governance challenges of designing and enforcing risk management approaches

Awareness is increasing that developing water quality regulations is not merely a technical question and comes with complex governance challenges. Both conservative and more lenient regulatory approaches recommend that standards should be 'adaptive' and integrate multiple factors such as other regulatory aspects (i.e., environmental discharge limit values), treatment capacities and technologies, enforcement capabilities, technical know-how and others (Table 5.2). Integrating all these interfaces can only be done through cross-administrative collaboration but also establishing links with the lower scales to incorporate contextual factors and design appropriate monitoring mechanisms (Evans et al. 2010).

Risk management approaches (such as the multi-barrier) are particularly challenging in terms of context-based planning and multi-scale coordination. The WHO (2006) recommends that "social feasibility of changing certain behavioral patterns [...] needs to be assessed on an individual project basis." Empirical experiments with farmers revealed that low-cost measures have the potential to reduce pathogens "especially if they are developed with the user" but

TABLE 5.2 Challenges and solutions for the development and implementation of agricultural reuse standards.

Challenge	Recommendation
Guidelines, frequently copied from developed countries, are directly adopted as national standards	Every country should adapt the guidelines based on local conditions and derive corresponding national standards.
Guidelines values are treated as absolute rather than target values	Guidelines values should be treated as target values, to be attained over the short-, medium- or long-term, depending on the country's technological, institutional and financial conditions.
Treatment plants that do not comply with global standards do not obtain licensing or financing	Environmental agencies should license, and banks should fund control measures that allow for stepwise improvement in water quality, even though standards are not immediately achieved.
No affordable technology leads to compliance with standards	Control technologies should reflect countries' financial conditions. The use of appropriate technology should always be pursued.
Standards are not enforced	Standards should be enforceable and enforced. Standard values should be achievable and allow for enforcement, based on existing and affordable control measures. Environmental agencies should be institutionally well developed to enforce standards.
Discharge standards are not compatible with water quality standards	The objective of pollution control is the preservation of the quality of water bodies. Discharge standards should be based on practical and justifiable reasons, assuming a certain dilution or assimilation capacity of the water bodies.
Number of monitoring parameters is not optimal (too many or too few)	The list of parameters should reflect the desired protection of the intended water uses and local laboratory and financial capacities, without excess or limitation.
No institutional development supports or regulates the implementation of standards	Efficient implementation of standards requires adequate infrastructure and institutional capacity to license, guide, monitor and control polluting activities and enforce standards.
Reduction of health environmental risks associated with compliance with standards is not immediately perceived by decision makers or the population	Decision makers and the population at large should be well informed about the benefits and costs associated with the maintenance of good water quality, as specified by the standards.

SOURCE: EPA 2012, adapted by authors.

"their success depends largely on the adoption rate which requires appropriate analysis of possible economic and social incentives" (Bos et al. 2010, 42). This requires strong coordination mechanisms between central-state institutions and users first to design adaptive regulations and second to incentivize enforcement. As explained below, this is still the most challenging aspect in institutionalizing such risk management approaches in MENA.

5.3. Issuing water quality regulations: comparative trajectories of five countries

The MENA countries have considerably different trajectories in terms of wastewater treatment and reuse growth (see Chapter 1). However, comparing the evolution of agricultural water reuse regulations between Egypt, Lebanon, Jordan, Morocco and Tunisia reveals three common historical periods, consistent with the evolution of the WHO and FAO international guidelines described above (Table 5.3).

TABLE 5.3 Historical development of agricultural water reuse quality regulations in five MENA countries.

Period / milestone	Policy orientation in agricultural water reuse	Main policies and quality regulations
1950–1975: **1973** *WHO First water reuse health guidelines*	First legal tests prohibiting wastewater discharge in the environment and the use of polluted water.	• Jordan Municipality Law *(No. 29/1955)* • Egypt regulation *(No. 93/1962)* • Tunisia Water Code *(1975)* • Lebanon *(Decree 8735/1974 and Decree 8765/1976)*
1975–1990: **1989** *WHO updated guidelines*	Development of national plans, projects and quality regulations for agricultural reuse in Jordan and Tunisia.	• Egypt first standards for drainage water reuse *(Law No. 48/1984)* • Jordan first standards for water reuse in agriculture *(Law No. 2/1982)* • Tunisia first standards for water reuse in agriculture and discharge of water in the environment *(1989)*
1990–2000: **1992** *FAO Water reuse agronomic guidelines*	Water reuse starts being integrated in most countries national water strategies. Reuse projects expand. Some countries update their water reuse standards.	• Water Act in Morocco *(1995)* • Jordan Wastewater management strategy including reuse *(1998)* • Tunisia First strategy of mobilization of water resources including water reuse *(1990)*
2000–Present: **2006** *WHO Multi-barrier approach*	Water reuse becomes a national goal in all countries. New strategies and regulations supported by International Organizations are developed to expand and improve reuse.	• Moroccan regulations on water quality for irrigation *(2002)* • Jordan update of reuse standards *(No. 893/2006)* • Egyptian Standards for Wastewater Reuse *(No. 501/2005)* revised in 2015; • First Lebanon water reuse guidelines under an FAO project *(2010)* • Ongoing Egypt Water Reuse Strategy supported by IWMI • Ongoing revision of Lebanon standards supported by IWMI *(2021)* • Ongoing revision of Tunisian standards *(2020)* • Jordan Water Substitution and Reuse Policy *(2016)*

5.3.1. 1920s–1970s: First pollution control regulations and restriction on wastewater reuse in the five countries

The first half of the twentieth century was a period of European mandates and state building in the MENA region. The first laws were promulgated establishing water as a public domain (see Chapter 3). Starting in the mid-1900s, the development of large state irrigation projects and the expansion of private pumping had dramatically increased water use. Water flows were reduced and as population and economic activities grew, the impact of pollutants increased. With awareness about pollution impact going global, the five governments issued regulations prohibiting the use of polluted waterways in irrigation. This was the case in Tunisia (Water Code issued in 1975), Jordan (Public Health Law in 1971) and Lebanon (Decree 8765 in 1976). In Egypt, using drainage water was restricted in the Nile Delta and other waterways and, by 1976, the government started to install monitoring stations on the Delta to monitor the quality of drainage water (Loutfy 2010).

5.3.2. 1980s–1990s: First wastewater reuse policies and regulations

Jordan and Tunisia were the first countries in the region to implement agricultural water reuse projects. Amongst the five studied countries, they were the only ones to regulate water reuse quality before the twenty-first century. Tunisia was a pioneer state in developing water reuse studies, policies and projects (Abu-Madi 2004; Ait-Mouheb et al. 2020; Choukr-Allah 2010; Condom et al. 2012). The first reuse project was implemented in La Soukra area as early as 1965 as a solution to water salinity problems. Aquifer recharge plans from treated water were also considered very early on (in 1989 in Nabeul) (Condom et al. 2012). The first (and only) reuse standards were issued in 1989 inspired by the WHO (1989) and the FAO (1992 guidelines. Besides the environmental drivers, Tunisia's pioneering efforts can be attributed to the leadership of a well-known researcher in the field.[7]

Jordan, constrained by its natural water scarcity, was one of the first countries to consider reuse as part of national water planning (Abu-Madi 2004; Choukr-Allah 2010). A first set of qualitative standards was issued at the end of the 1980s[8] and a few years later, new qualitative standards for industrial and domestic effluents were produced based on the WHO guidelines (Nazzal et al. 2000; Abu-Madi 2004).[9]

Jordan and Tunisia were noticeably the first to develop national-scale strategies for reuse, respectively in 1990 and 1998. This translated into a substantial increase in reuse ratios in both countries. By the end of the 1990s, about 67 million m^3 were used for irrigation in different parts of Jordan. About 52 million m^3 was indirectly used for unrestricted irrigation in the Jordan Valley after blending with freshwater in wadis and King Talal Dam. About 15 million m^3 was directly used for restricted irrigation indoor and within the surroundings of existing (Abu-Madi 2004; 36). In Tunisia, the amount of reused water tripled (Abu-Madi 2004).

In Egypt, water reuse essentially takes place in the Nile Delta where irrigation effluents, often mixed with domestic and industrial pollutants, are discharged in drainage canals and reused indirectly. Water reuse became an official goal in national water strategies in 1984 with a law that governed the disposal and reuse of drainage water (Loutfy 2010). Until the beginning of the next century, the goal was to minimize wastewater discharge to drains and separate pollutants from irrigation water while plans for direct reuse were not yet on the table (Loutfy 2010; see Chapter 3).

In Morocco, the Water Act of 1995 represented a turning point in terms of regulating pollutant discharge and setting the ground for the mobilization of treated wastewater. However, no major investment was done until the end of the 1990s when the need for irrigation water pushed farmers in many areas to informally tap into raw wastewater from nearby cities (Ait-Mouheb et al. 2020).

[7]Dr. Akissa Bahri started her career in the Research Institute for Agricultural Engineering in Tunisia and became Minister of Agriculture. She was very influential in research and policy-making in the field of agricultural water reuse in Tunisia and the MENA region. Interviewed in September 2021, Dubai.

[8]Included in Law No. 2 in 1989.

[9]Respectively, Standard 202/1991 and Standard 893/1995.

In Lebanon, the civil war from 1975 to 1990 slowed down all public water and wastewater projects. Only some small-scale WWTPs were built by external funds and community initiatives. During the reconstruction period, wastewater treatment was one of the major governmental goals and received tremendous attention from international banks and NGOs, but reuse has only appeared in donors' agendas in the past two decades (Eid-Sabbagh et al. 2022).

5.3.3. 2000–onward: Large developments in infrastructure, policies and regulations

The beginning of the millennium saw an increased attention toward sanitation and reuse in Lebanon, Egypt and Morocco. Driven by international development agendas, several countries underwent major administrative and institutional reforms in the wastewater sector (see Chapter 3). Encouraged by the World Bank, Lebanon issued a new water law in 2000 (Law 221) and created four regional water and wastewater establishments (RWWEs) to merge the 21 earlier decentralized water offices and take over the responsibility of managing wastewater networks and facilities from municipalities. The Ministry of Environment was created in 2002 (Law 444) with the support of UNDP.

In Egypt, two major agencies were created in 2004: the Egyptian Water Regulatory Agency (EWRA) responsible for the regulation, monitoring and evaluation of all activities related to water supply services (Presidential Decree No. 2004) and the Holding Company for Water and Wastewater (HCWW) and its 25 (now 27) affiliated companies, to manage all water and wastewater facilities.

In Morocco, the 2006 National Sanitation Plan was issued (French acronym PNA) and aimed to increase the overall treatment from 8% to 60% by 2020 (Ait-Mouheb et al. 2020).

In the three countries, water reuse started to be incorporated within national policy objectives for water management. In the early 2000s in Egypt, the Ministries of Agriculture and Land Reclamation (MALR) and Water Resources and Irrigation (MWRI) set a plan to reclaim 1.2 million ha by 2017, utilizing both treated water from large municipal WWTPs and agricultural drainage water from the Delta (Loutfy 2010). The plan targeted water reuse for non-food crops such as cotton, flax and trees with the goal of reducing wood and timber imports (Loutfy 2010).

In 2009, the Moroccan National Water Plan aimed for a reuse rate of 19% by 2020 and 31% by 2030 (Ait-Mouheb et al. 2020).

In 2012, the Lebanese National Water Sector Strategy included water reuse as one of the means to ensure water security (MEW 2012). During this period, the three countries developed the first quality regulations for agricultural water reuse. Inspired by the WHO (1989) guidelines, Morocco released their regulations on water quality for irrigation in 2002. The Egyptian Ministry of Agriculture released its first Code of Practice for Wastewater Reuse in 2005 and revised it in 2015. In Lebanon, the first *Guidelines for wastewater reuse and sludge* *reuse*, were published in 2010 under an FAO project (FAO 2010) but efforts for their ratification is still ongoing (Table 5.3 above).

Jordan and Tunisia, where good progress was made in wastewater treatment, directed their focus on improving reuse policies and regulations. Jordan issued a new version of the reuse standards in 2006 following the same approach promoted by the WHO (1989). It developed several reuse policies such as the Water Substitution Policy in 2016 and has been working on developing institutional arrangements to organize the distribution of treated wastewater between public institutions and farmers (Regulation No. 7/2016). Tunisia updated its reuse standards twice in 2018 and 2020 but those are still not formally endorsed (Table 5.3 above).

5.4. Regulating water reuse quality in MENA: trends and influence by international guidelines

The following section analyzes the main regulatory aspects adopted in each of the five countries as compared to the main international guidelines (see first section of this chapter) and other countries in the region. Other countries have been selected depending on data availability. The focus is put on regulations for human-health protection, more particularly pathogen thresholds and restrictions put on farmers' practices. Other key physicochemical and agronomic parameters are also compared as well as on-farm practices recommended both for pathogen control and crop productivity. The analysis is based on a compilation of the standards included in official regulations or found in the literature when access to official documents was not possible.

5.4.1. Human health protection

Predominance of the WHO (1989) approach

The five selected MENA countries – Egypt, Lebanon, Morocco, Jordan and Tunisia – have all adopted the regulatory approach of the 'fixed standards' (as opposed to the health-based approach) where it is mandatory that treated water complies to a set of human-health, physicochemical and agronomic parameters for it to be used in irrigation. Four of the five countries have followed the approach set by the WHO (1989) guidelines and identified different categories of 'use conditions' similarly to the approach presented in Table 5.1 (above). The exception is Tunisia where only one category of water quality exists according to the first standards issued in 1989. The revision of the Water Code (2012) and many pioneering research efforts to assess local health and agronomic risks (Bahri 2001; Caucci and Hettiarachchi 2018) still have not translated into official regulations.

Table 5.4 presents the different 'use conditions' categories as defined in the regulations and guidelines of 12 MENA countries, as well as in four international guidelines presented in the Section 1: EPA (2012), WHO (1989), WHO (2006) and the Mediterranean guidelines issued by UNEP (2005). It shows that while most countries were influenced by the 1989 WHO classifications, only two (Morocco and Iran) have adopted the same proposed uses without adaptation. Lebanon and Jordan's categories are different than the WHO but comparable (three main categories and similar uses). Egypt has opted for four categories such as in the UNEP Mediterranean guidelines (2005), but target uses are classified differently. In general, categories vary greatly between countries' regulations which makes standards not easily comparable. Despite these variations, important trends can be found when it comes to microbial thresholds and food crop restrictions as seen in the following sections.

Pathogen thresholds and crop restrictions

High-income countries (mostly GCC countries such Kuwait, Oman, Saudi Arabia and the United Arab Emirates) are often presented as following more stringent standards than the lower-income ones (WaDImena 2008; Choukr-Allah 2010). A closer comparison of bacterial thresholds in the region leads to a more nuanced conclusion. The majority of the five coun-

TABLE 5.4 'Use conditions' categories in 12 MENA countries.

Standards	Target use
EPA 2012	A: Food crops
	B: Processed food crops
	C: Non-food crops
Mediterranean guidelines (UNEP 2005)	I: a) Residential reuse: private garden watering, toilet flushing, vehicle washing; b) Urban reuse: irrigation of areas with free admittance (greenbelts, parks, golf courses, sport fields), street cleaning, firefighting, fountains and other recreational places; c) Landscape and recreational impoundments: ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).
	II: a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees; b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed; c) Industrial reuse (except for food, beverage and pharmaceutical industry).
	III: Irrigation of cereals and oleaginous seeds, fiber and seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler irrigated), plant nurseries, ornamental nurseries, trees, green areas with no access to the public.
	IV: a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practices (such as plastic mulching, support, etc.) guaranteeing absence of contact between reclaimed water and edible part of vegetables; b) Irrigation of crops in category III with trickle irrigation systems (such as drip, bubbler, micro-sprinkler and subsurface); c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public; d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.
WHO 2006	Unrestricted
	Restricted
WHO 1989	A: Irrigation of crops likely to be eaten uncooked, sports fields, public parks
	B: Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees
	C: Localized irrigation of crops in cat. B if exposure of workers and the public does not occur
Abu Dhabi 2018	Unrestricted irrigation
	Restricted irrigation
Egypt 2015	A: Fruit crops; green spaces in educational facilities and public and private parks;
	B: Fruit crops; medicinal crops; dry grains and cooked and processed vegetables, of all types;
	C: Seeds; all types of seedlings which are later transplanted to main fields; roses and cut flowers; trees suitable for afforestation of highways and green belts; all fiber crops; grass and legume fodder crops; berries for silkworm production; all nurseries or ornamental plants and trees;
	D: Solid biomass crops; liquid biomass crops; crops used for producing cellulose; timber trees.

Standards	Target use
Lebanon 2010	I: Fruit trees and crops that are eaten cooked; parks, public gardens, lawns, golf courses and other areas with direct public exposure;
	II: Fruit trees; lawns, wooded areas and other areas with limited public access, roadsides outside urban areas; landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed;
	III: Irrigation of cereals and oleaginous seeds, fiber and seed crops; crops for canning industry, industrial crops; fruit trees (except sprinkler-irrigated); plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.
Iran 2010	A: Irrigation of crops likely to be eaten uncooked, sport field, public parks;
	B: Irrigation of cereal crops, industrial crop, fodder crops, pasture and trees;
	C: Localized irrigation of crops in category B if exposure of workers and the public does not occur.
Jordan 2006	A: Cooked vegetables, parks, playgrounds and roadsides within city limits;
	B: Fruit trees, roadsides outside city limits and landscape;
	C: Field crops, industrial crops and forest trees.
	No name: Cut flowers;
Saudi Arabia 2006	Unrestricted irrigation;
	Restricted irrigation
Palestine 2003	A: High water quality;
	B: Good water quality;
	C: Medium water quality;
	D: Low water quality.
Morocco 2002	A: Crops likely to be eaten raw, field sports, public gardens;
	B: Cereal crops, industrial and forage crops, orchards and pastures;
	C: Crops of category B if they are irrigated under drip irrigation and if agricultural workers and farmers are not exposed.
Syria 2002	A: Irrigation of cooked vegetables crops and public areas;
	B: Processed food crops, fruit trees and other urban areas;
	C: Industrial crops and forestry.
Kuwait 2002	One water category
Oman 1995	A: Vegetables likely to be eaten raw, fruit likely to be eaten raw and within two weeks of any irrigation;
	B: Vegetables to be cooked or processed, fruit if no irrigation within two weeks of cropping, fodder, cereal, seed crops, pasture no public access.
Tunisia 1989	Only one crop category

SOURCES: EPA 2012; WHO 2006a; UNEP 2005; WHO 1989; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).

tries have set more stringent microbial limits for food crops than those recommended by the 1989 WHO guidelines for the same use category (1,000 bacteria/100 mL) (Figure 5.3). Both Lebanon and Jordan have opted for 200 *E. coli*/100 mL.[10] This is the most stringent threshold recommended by the WHO (1989) for the irrigation of public spaces (Figure 5.4). The same

[10]Different bacterial indicators are used. See notes in Figures 5.3 and 5.4.

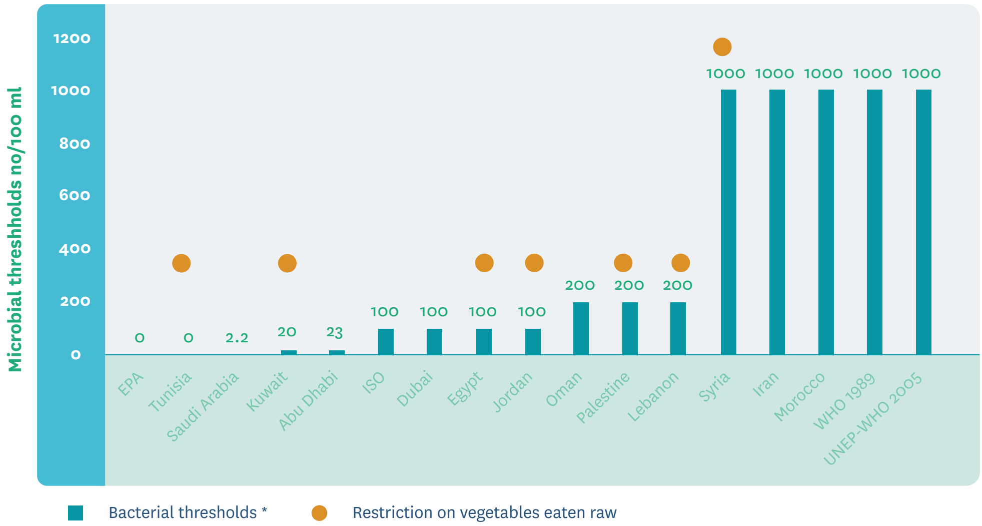

FIGURE 5.3 Microbial threshold and crop restrictions for food crop irrigation.
SOURCES: EPA 2012; ISO 2015; UNEP 2005; WHO 1989; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).
NOTES: *Microbial indicators are different from one standard to another: EPA, WHO. Lebanon, Iran, Saudi Arabia, Morocco, Syria and Oman use fecal coliforms, while Palestine, Jordan and Egypt use *E. coli*; WHO-UNEP, Abu-Dhabi uses both indicators equivalently. Kuwait uses either fecal coliforms or total coliforms. The latter has a threshold of 400/100 mL.

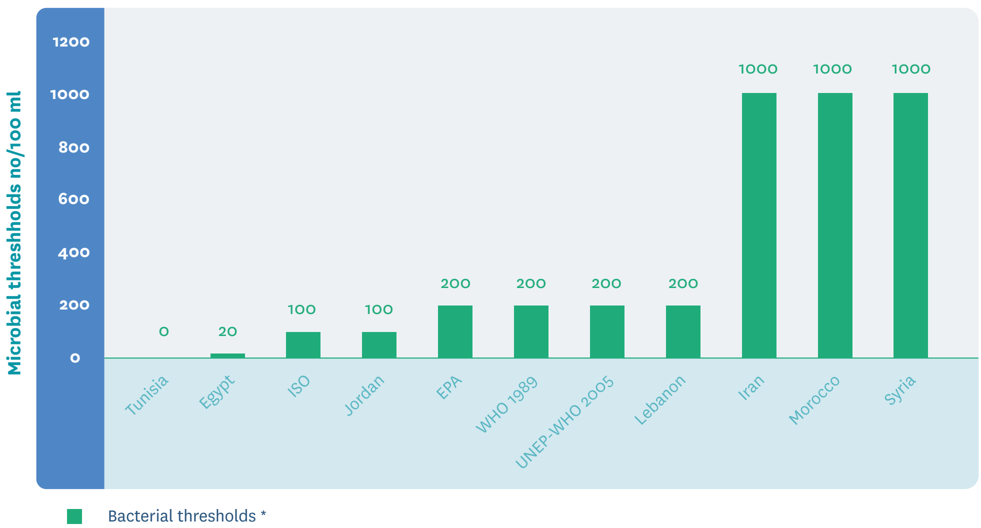

FIGURE 5.4 Microbial thresholds for public parks and landscape irrigation.
NOTES: *Microbial indicators are different from one standard to another: EPA, WHO Lebanon, Iran, Morocco and Syria use fecal coliforms, while Jordan and Egypt use *E. coli*; WHO-UNEP uses both indicators equivalently. SOURCES: EPA 2012; ISO 2015; UNEP 2005; WHO 1989; ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013; Official Standard NT 106.002/1989 (Tunisia).

threshold was adopted for the same category in the Mediterranean guidelines (UNEP 2005) while thresholds for food crops were the same as those recommended by the 1989 WHO guidelines. Egypt has set the limit at 100 fecal coliforms/100 mL (the same as Oman) and Tunisia at 0 bacteria, which is more stringent than Saudi Arabia, Kuwait and Abu Dhabi and closer to the Californian Model. Morocco is the only country adopting the 1989 WHO-recommended threshold for food crops.

Furthermore, only Morocco allows irrigating vegetables that can be eaten raw, while the four others completely forbid it. GCC countries are less restrictive in terms of allowed end-uses, particularly concerning vegetable-eaten-raw irrigation. Three out of four of the latter countries (Kuwait being the exception) allow for irrigating vegetables that can be eaten uncooked, which makes them less restrictive in terms of irrigating food crops.

As noted in the next sections, crop restriction is hard to enforce in practice and often leads to informal reuse. When formulating the Mediterranean guidelines, this topic "has been the subject of so intense controversies among the experts" (UNEP 2005; p.21). It was finally decided that "Vegetables to be eaten cooked, such as potatoes, leeks, beans, etc. and not exclusively grown for the canning industry, are included in the same category as vegetables to be eaten raw, for they are often grown in the same fields, irrigated with the same water (UNEP 2005; p.21).

Restrictions on irrigation systems

The five countries' regulations (guidelines in the case of Lebanon) have introduced restrictions on irrigation techniques as an on-farm management barrier. Egypt allows using "small sprinklers with a horizontal angle of no more than 11 degrees" for irrigating public spaces (Category A), food crops including vegetables to be cooked and processed and fruit trees (Category B). Sprinklers are restricted in categories C and D (seedlings and non-food crops). Lebanon allows the use of sprinklers only for categories II and III water, which include fruit trees but exclude vegetables and only if a "buffer zone of 300 m" is respected between excluded crops. Jordan, Tunisia and Morocco restrict the use of sprinklers for all categories. The WHO (1989) and the Mediterranean guidelines (UNEP 2005) both provide freedom for countries to allow for the use of sprinklers (Table 5.5).

5.4.2. Physicochemical parameters

The main physicochemical parameters have been compiled for the first category of water for 12 MENA countries' official regulations or guidelines (Lebanon) and are presented in Table 5.6. Generally, it shows that countries did not adopt the same physicochemical parameters to monitor and have different thresholds for the same parameters. Biological oxygen demand (BOD5) and total suspended solids (TSS) are adopted in 11 countries' standards (except Morocco for BOD5 and Tunisia for TSS), chemical oxygen demand (COD) is adopted in seven standards, the COD in six standards, turbidity (NTU) in five standards and the dissolved oxygen (DO) only in one standard (Jordan).

Our five countries of interest have various levels of stringency regarding the different parameters. The highest limit value for BOD5 has been set by Tunisia and Jordan (30 mg/L) and the lowest for Egypt (15 mg/L). Other governments in MENA such as Abu Dhabi, Saudi Arabia and Oman register lower thresholds (10, 10 and 15 mg/L, respectively) which can be explained by the higher level of treatment in these countries (Choukr-Allah 2008). The COD parameter is only monitored in three countries (Lebanon, Jordan and Tunisia) with Lebanon having the

TABLE 5.5 Main standards and restrictions for pathogens control.

Country	Category	Bacteria (no./100 mL)*	Intestinal nematodes (eggs/L)	Vegetables eaten raw allowed	Sprinkler irrigation allowed
WHO 1989	A	≤1,000 for food crops; 200 for public spaces	≤1	Yes	Yes, if conditions allow
	B	No standard recommended	≤1	No	No
	C	Not applicable	Not applicable	No	No
Mediterranean-Guidelines UNEP 2005	I	≤ 200	≤ 0.1	Not applicable	Yes
	II	≤ 1,000	≤ 0.1	Yes	Yes
	III	<10-5	≤ 1	No	Yes except for fruit trees
	IV	Not required		No	No
Egypt	A	20	≥1	No	Yes (Small sprinklers with a horizontal angle of no more than 11 degrees)
	B	100	_	No	Yes (Small sprinklers with a horizontal angle of no more than 11 degrees)
	C	1,000	_	No	No
	D	_	_	No	No
Jordan	A	100	≤1	No	No
	B	1,000	≤1	No	No
	C	_	≤1	No	No
	D	<1.1	≤1	No	No
Lebanon	I	≤ 200	<1	No	No
	II	≤ 1,000	<1	No	Yes (Buffer zone of 300 m must be respected)
	III	_	<1	No	Yes (Buffer zone of 300 m must be respected)
Morocco	A	< 1,000	0	Yes	No
	B	_	0	No	No
	C	_	0	No	No
Tunisia			1	No	No

NOTES: * Microbial indicators are different from one standard to another: WHO, Lebanon and Morocco use fecal coliforms, while Jordan and Egypt use E. coli; UNEP uses both indicators equivalently. *SOURCES*: UNEP 2005; WHO 1989; ECP 2015 (Egypt); FAO 2010 (Lebanon); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); MEDAWARE 2003 (Morocco); Official Standard NT 106.002/1989 (Tunisia).

higher threshold (125 mg/L) followed by Jordan (100 mg/L) and Tunisia (90 mg/L). GCC countries have either higher or lower threshold values. Amongst the 12 countries, Morocco adopted the highest limit value for TSS and is the only standard providing two different values according to the used irrigation technique (100 mg/L for sprinkler and 200 mg/L for gravity). It is followed by Lebanon (60 mg/L), Jordan (50 mg/L), Iran and Syria (50 mg/L) and Palestine (30 mg/L). As for the BOD5 parameters, Egypt's TSS threshold is closer to GCC countries' standards (15 mg/L like Kuwait and Oman). This can be related to Egypt's national objective of implementing high-level treatment technologies.

TABLE 5.6 Physicochemical parameters for the best category of treated effluents in different regulations.

	Target use/ Water Category	BOD5 (mg/L)	COD (mg/L)	DO (mg/L)	TSS (mg/L)	Turbidity (NTU)
EPA (2012)	Category A	10			5	2
WHO-UNEP (2005)	Category I				≤ 10	
Abu Dhabi	Unrestricted irrigation	10			10	5
Egypt	Category A	15			≤ 15	≥ 5
Lebanon	Crops of Category I	25	125		60	
Iran	Category A	21			40	
Jordan	Category A	30	100	More than 2	50	10
Saudi Arabia	Unrestricted irrigation	10			10	5
Palestine	Crops irrigated from high quality water	20	50		30	
Morocco	Category A				100 (sprin-kler); 200 (gravity)	
Syria	Category A	30	75		50	
Kuwait	Unrestricted irrigation	20	100		15	
Oman	Category A	15	150		15	
Tunisia	One category	30	90			30

SOURCES: EPA 2012; UNEP 2005; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).
NOTES: BOD5 (biological oxygen demand) indicates the amount of oxygen which bacteria and other microorganisms consume in a water sample during the period of five days at a temperature of 20°C. The COD (chemical oxygen demand) value measures how much oxygen the chemical purification processes in the wastewater consume. The higher the value, the less effectively the water is purified. DO (dissolved oxygen) is the amount of oxygen that is present in the water and is a direct indicator of an aquatic resources' ability to support aquatic life. TSS (Total Suspended Solids) is a measurement of the total solids in a water or wastewater sample that are retained by filtration. Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample.

5.4.3. Agronomic parameters and trace elements

The compilation of agronomic parameters showed a wide variety of regulatory approaches amongst countries where different classifications were adopted and varying numbers of parameters (Table 5.7). As per the classification adopted by FAO (1992), Lebanon and Jordan identified three degrees of restrictions on use (none, slight and severe). Egypt identified two types of use, 'long term' and 'short term' and other countries such as Morocco did not distinguish between level of restriction on uses. The highest number of parameters to monitor was adopted by Jordan (11) while Lebanon, Egypt and Morocco specify nine parameters to monitor.

TABLE 5.7 Classification and agronomic parameters adopted to regulate crop production in MENA.

MENA countries	Approach used to identify risks	# of agronomic parameters	Specified Parameters
FAO (1992)	Classified into three categories according to 'degree of restriction on use' (none, slight, severe)	14	pH; EC; TDS; SAR; Na^+; Cl^-; Cl_2; HCO_3^-; B; H_2S; Fe; Mn; TKN Threshold values of Na^+ and Cl^- differ according to irrigation system (sprinkler lower than surface)
Abu Dhabi (2018)	Same categories as for key parameters (Unrestricted; restricted)	9	pH; EC; TDS; SAR; Na^+; Cl^-; HCO_3^-; Res Cl_2; B
Egypt (2015)	Classified into two categories 'Long-term use' and 'short-term use'	9	TDS; SAR; Na^+; Mg^{2+}; Ca^{2+}; HCO_3^-; PO_4; SO_4; B
Lebanon (2010)	Classified into three categories according to 'degree of restriction on use' (none, slight, severe);	9	pH; EC; TDS; SAR; Na^+; Cl^-; TKN; HCO_3^-; Res Cl_2; B; Threshold values of Na^+ and Cl^- differ according to irrigation system (sprinkler lower than surface)
Iran (2010)	One category	10	pH; EC; TDS; SAR; Na^+; Cl; NH_4; HCO_3; PO_4; B
Jordan (2006)	Classified into three categories according to 'degree of restriction on use' (none, slight, severe)	11	pH; EC; TDS; SAR; Na^+; Cl; NO_3; HCO_3^-; PO_4; Res Cl_2; B
Saudi Arabia (2006)	Same categories as for key parameters (Unrestricted irrigation; restricted irrigation)	5	pH; TDS; NO_3; Res Cl_2; B
Palestine (2003)	Same categories as for key parameters (A, B, C, D)	6	pH; TDS; Cl (different values according to irrigation system); NO_3; HCO_3; Res Cl_2
Morocco (2002)	Only one category	9	pH; EC; TDS; Na+; Cl; NO_3; HCO_3^-; SO_4; B Threshold values of Na+ and Cl differ according to irrigation system (sprinkler lower than surface)
Syria (2002)	Same classification as for key parameters (A, B, C, D)	14	pH; TDS; SAR; Na^+; Mg; Ca; Cl; NO3; NH_4; HCO_3^-; PO_4; SO_4; Res Cl_2; B
Kuwait (2002)	Only one category	8	pH; EC; TDS; TKN; NH_4; PO_4; Res Cl_2; B
Oman (1995)	Different then for key parameters (food crops; non-food crops)	11	pH; EC; TDS; Na^+; Mg^{2+}; Cl; TKN; NO_3; NH_4; PO_4; B

SOURCES: EPA 2012; FAO 1992; UNEP-WHP 2005; WHO 1989; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).

5.5. Implementing risk management approaches: practices and challenges

While MENA countries are deploying efforts in improving water quality regulations, adaptive risk management approaches recommended by international guidelines (such as WHO 2006a and EPA 2012) were found to be poorly adopted. The issue of informal (thus unsafe) reuse practices is generally not addressed in regulatory efforts, which remain focused on the 'formal' sector (Tawfik et al. 2021). In existing reuse schemes, restrictive approaches are still privileged with insufficient incentives or support for farmers to adopt the imposed practices. The following section illustrates these problems and attempts to explain the institutional and social processes that lead to non-adaptive regulations.

5.5.1. A poor adoption of risk management orientations

The regulatory measures adopted in the five countries show that efforts are focused at regulating effluents discharged from existing treatment plants while unsafe practices remain poorly addressed. Egypt is an archetypal example where polluted water is tapped informally in the Nile Delta drainage system to irrigate all types of crops, including vegetables to be eaten cooked and raw (Loutfy 2010). While the government is implementing large treatment plants in other parts of the country with plans to expand 'safer' crops (timber trees), Egypt's largest agricultural areas remain irrigated with poor quality water. The management of the risk of informal reuse does not seem addressed in Egypt new water regulations (2015).

While 'best practices' (risk-reduction measures) are found in most regulations and guidelines, they come under the form of recommendations and are accompanied with restrictive compulsory measures such as complete restriction on crops and irrigation techniques. On the other hand, capacities of enforcement are low and alternatives not always feasible for farmers. In Tunisia, the government substituted freshwater with treated effluents in several irrigation schemes. In one of the reuse schemes (Cebala), restrictions on irrigating vegetables pushed farmers to keep large portions of land uncultivated; and in Ouzarah and in Al-Resalah, farmers requested authorities to reallow the use of freshwater (Abu-Madi 2004). The same practices were recently observed in Jordan nearby 'Al Kherbe Al Samra' WWTP. There, contracts between the water company and farmers impose cultivating fruit trees and forage crops, but many farmers were seen to be informally planting vegetables.[11]

In Lebanon, treatment volumes are low and organized reuse systems are still lacking.[12] In the Bekaa Valley, the pollution of the Litani River has induced serious health impact on residents and the implementation of conventional treatment plants accumulated tremendous delays (Eid-Sabbagh et al. 2022). Informal reuse is widespread but alternative or complementary risk management measures (e.g., unconventional treatment, pathogen control points at farmer or consumer levels as recommended by WHO) are poorly considered in planning and regulations. On a national level, areas with 'reuse potential' typically include leafy vegetables as

[11] Interview with a Jordanian researcher in January 2022.

[12] The exception is in Ablah where a small reuse system was implemented by an EU project in 2015 (see Eid Sabbagh et al. 2022).

shown by a recent IWMI study (Eid-Sabbagh et al. 2022). Conversely, the guidelines promulgated in 2010 completely forbid irrigating vegetables eaten raw as well as the use of sprinklers. The Lebanese Agricultural Research Institute (LARI) conducted efforts to empirically test on-farm risk management practices in the Bekaa but such efforts are done on project level, are dependent on external funding[13] and are not systematically linked to the formulation of new regulations. Furthermore, their translation into risk management plans is yet another challenge given the multiplicity of administrations and the fragmented planning in the Lebanese wastewater sector (Eid-Sabbagh et al. 2022; see Chapter 3).

5.5.2. Parallel planning and lack of institutional leadership

The Jordanian experience illustrates the institutional challenges of implementing the risk management approach promoted by WHO. In 2014, the Ministry of Irrigation developed the Irrigation Water Quality Guidelines using the WHO (2006a) concepts of risk assessment, health-based targets and health protection measures. For instance, the formulated guidelines allow irrigating vegetables eaten raw under specific measures which is a forbidden practice in the official standards. According to Kassab (nd), these guidelines were not incorporated in the recent Agriculture Law of 2016 due to institutional disagreements. A Jordanian researcher involved in water quality regulation processes in the country explains that implementing such multi-stakeholders' plans cannot be done without a political decision from the central level such as the Council of Ministers. In her view, a 'higher' authority should institutionalize such plans so that administrations have a legal framework and a political incentive to implement the different 'control points' of the multi-barrier approach (see Section 3, Chapter 4).

Institutional fragmentation, an issue commonly underlined in MENA (Choukr-Allah 2008; Ait-Mouheb et al. 2010) further complicates stakeholder coordination. For example, the planning process of treatment plants is often undertaken by agencies which scope or expertise does not encompass irrigation and agricultural reuse. In Jordan and Tunisia, for instance, wastewater treatment facilities were long designed in compliance with environmental standards (discharge in the environment) rather than those formulated for reuse (Abou Madi 2004). This has improved in Jordan where administrations in charge of operating treatment plants are now directly responsible for establishing subscription contracts with users. However, monitoring of crops is under the responsibility of the Ministry of Agriculture, whose staff is geographically distant from the field.[14]

In Lebanon, the administrations responsible for planning or operating treatment plants were found to follow environmental discharge standards and are rarely aware about the existence of the issued reuse guidelines (FAO 2010).[15] Moreover, while the design of new treatment plants starts to include reuse outlets, overall planning is not coordinated with administrations concerned with irrigation management, municipalities or users (Eid-Sabbagh et al. 2022). In Morocco, despite the governmental efforts deployed to integrate sanitation and

[13]Research experiments were conducted in 2019 and 2020 as part of ReWater MENA project. LARI researchers performed the trial and published research papers.

[14]Interview with a Jordanian researcher in January 2022.

[15]Personnel observation.

reuse in unified plans, some studies suggest that there is no “formally agreed-upon process for formulating and designing new [reuse] projects” (Ait-Mouheb et al. 2020). Further to this gap between treatment design and reuse policies, studies regularly mention an issue in treatment plants’ performance due to under-staffing, lack of technical expertise and institutional fragmentation, which should be resolved to comply to regulations (Choukr-Allah 2008; Ait-Mouheb et al. 2020).

5.5.3. The technocratic tradition of formulating regulations

Favoring ‘strict’ regulations is also explained by the socio-institutional framework in which standards are formulated. Setting standards often happens through ‘technical committees’ formed by representatives of ministries (of health, environment, water and irrigation depending on the countries). They are usually mid-level officials coming from a technical background (e.g., chemists, agronomists and biologists) and aiming for the best possible conditions for health safety or crop productivity. In such settings, the discussion is more often focused on standards and parameters as ‘absolute values’ (EPA 2012) rather than framed in the larger socio-economic and institutional context. Institutional considerations such as administrative capacities and enforcement, or questions of farmers’ practices and incentives, are not systematically brought on the table. In Jordan and Lebanon, these meetings are organized by the respective ‘Standard Institution’ of each country. In Lebanon, the main committee members invited are mostly water quality experts and agronomists with limited experience in institutional aspects of the wastewater sector (planning, institutional mandates and mechanisms), practical questions of WWTP operation or farmers’ practices and challenges[16]. The context seems to be similar in Jordan, where officials involved in such discussions are poorly aware of the practical challenges of enforcing regulations[17]. In both Lebanon and Jordan’s case, farmers or communities’ representatives are not part of these committees, which means that issues of agricultural practices, or wider questions of pollution impact are hardly discussed with users. In Jordan, “farmers can attend if deemed adequate, but they don’t have the right to vote on decisions”.[18] This shows that concepts of the ‘Learning Alliance’ (Evans et al. 2010) promoted by international organizations, remain poorly institutionalized and translated to practice. While projects aim at forming multi-level stakeholder’s platform, they are often conditioned by the choice of representatives of the ministries, whose backgrounds are not always consistent with the discussion.

5.5.4. Social perceptions and institutional responsibilities

Relaxing microbial thresholds is often perceived as ‘irresponsible’ or even an ‘unethical’ decision. In Tunisia, officials meeting to set new health-risk assessments are described as having a traditionally protective approach toward human health risks (Caucci et al. 2018). In Lebanon, a high-level official invited to a discussion on revising FAO guidelines based on the ‘WHO-multi barrier approach’ said that “more research needs to be done since relaxing

[16]Personnel observation of the main author.

[17]Interview with a Jordanian researcher in January 2022.

[18]Ibid.

standards has an impact on peoples' health."[19] Protective approaches have been described in one of our interviews as a sterile strategy of "passing the buck" where "officials go for decisions that are less risky but turn a blind-eye on questions of capacities of enforcement." As deplored by a key informant, "Strict thresholds often remain just a number on papers. This is not a responsible attitude in my opinion because removing the responsibility from one's shoulder does not mean safety will improve."[20]

5.6. Conclusion

This chapter analyzed the regulations and guidelines adopted by five MENA countries (Egypt, Jordan, Lebanon, Tunisia and Morocco) to manage the safety of water reuse in irrigation. It specifically focused on human health protection regulations and assessed countries' efforts and challenges in developing context-based regulatory approaches as recommended in recent international guidelines such as the WHO (2006) and EPA (2012).

It showed that the five countries still follow a standardized model targeting the formal waste-water sector where treated effluents need to comply to a fixed set of standards to be considered safe for reuse. Four countries (Egypt, Jordan, Lebanon and Morocco) adopted the model developed by WHO (1989) and three of them (Morocco being the exception) have adapted it with more stringent microbial thresholds and a complete restriction on vegetables to be eaten raw. Tunisia, despite many attempts to issue more adaptive regulations, still adopts its 1989 standards, which are closer to the 'zero risk' Californian Model.

Overall, the five countries adopt a top-down approach to controlling safety with complete restrictions on certain crops and irrigation techniques. Enforcement is often ineffective with farmers having poor incentives or support to find alternative practices. Furthermore, regulations are only applied to planned reuse projects while informal reuse remains poorly located and risks left unmitigated.

The WHO multi-barrier approach issued in 2006 has been widely promoted in the region but is not reflected in countries' regulations. While some initiatives such as in Jordan and Tunisia developed guidelines based on the concepts of 'health-based targets' and 'risk management,' those remain indicative and were not translated in risk management plans or adaptive regulations. Several factors hinder the design and implementation of such adaptive approaches such as the lack of institutional leadership on coordinating the tasks of diverse and sometimes competing administrations, the technocratic institutional processes of formulating standards and reluctance to take decisions that might be perceived as unethical or entail additional responsibilities.

[19]Minutes of Meeting, LIBNOR (November 31, 2021). This meeting was supported by IWMI and LARI researchers, where LARI presented the results of its field trials and the impact of on-farm practices on pathogen reduction was part of the discussion.

[20]Interview with a Jordanian researcher in January 2022.

On a more positive note, the study identified several research initiatives and field experiments aiming at studying risk management measures with the goal to propose guidelines adapted to local conditions. Knowledge should be shared with decision-makers in appropriate institutional settings, given visibility and supported to influence regulations and policy practices.

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